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Inland Eastex
Evadale, Texas

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Daniel J. Habes, Sherry Baron, and Dorothy Wigmore of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Desktop publishing by Juanita Nelson. Review and preparation for printing was performed by Penny Arthur.

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SUMMARY

On January 13, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request from employees at the Inland Eastex paper mill, Evadale, Texas, to evaluate repetitive motion injuries of the upper extremity and back associated with the core saw job in the finishing and shipping department. On April 29 and 30, 1998, NIOSH representatives conducted a site visit at the plant. This visit included videotaping of the core saw and core plugging jobs, review of injury and illness logs, and distribution of a medical and musculoskeletal disorders symptom questionnaire to the workers.

Physical stresses associated with the work tasks included lifting and carrying plugs and cores, pushing carts loaded with cores, and repetitive motions and impulse vibration to the upper extremity from hammering plugs into place. The amount of time workers spent performing their duties precluded the consistent use of a portable plugging machine, which relieved workers from hammering, but required more time to use.

Five of eight workers were interviewed and completed questionnaires. Four of these workers complained of shoulder pain and one reported forearm pain. All five workers attributed their pain to plugging cores. Elbow and back pain was also reported. Occupational Safety and Health Administration (OSHA) Log and summary of Occupational Injuries and Illnesses (OSHA 200 log) showed a steady increase in the incidence rate of reported injuries and illnesses in the finishing department from 8.7 per 100 workers in 1994 to 22.8 per 100 workers in 1997. These figures coincided with the gradual increase in the number of cores plugged in the finishing department during the same time period.

NIOSH investigators conclude that the jobs in the core saw area pose a risk of injury to the back and upper extremity of the workers. Lifting boxes of plugs, pushing carts of cores, and hammering plugs were the most hazardous activities. A portable plugging machine effectively inserted plugs into cores, but it conflicted with the work flow and time constraints inherent in the core saw area. Recommendations for changes in equipment and worker practices aimed at reducing the number of injuries and illnesses in the core saw area are offered in this report.

KEYWORDS: SIC 2621 Paper Mills, ergonomics, repetitive motion, lifting, hammering tasks, low back pain, upper extremity musculoskeletal disorders, shoulder pain, extended and rotating work shifts.

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INTRODUCTION

On January 13, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request from employees at the Inland Eastex paper mill, Evadale, Texas, to evaluate repetitive motion injuries of the upper extremity and back associated with the core saw job in the Company's finishing and shipping department.

On April 29 and 30, 1998, NIOSH representatives conducted a site visit at the plant. The site visit included an opening conference attended by management and union representatives, a general tour of the production facility, videotaping of the core saw and core plugging jobs, review of medical records and the Occupational Safety and Health Administration (OSHA) Log and Summary of Occupational Injuries and Illnesses (OSHA 200 log), and distribution of a medical and musculoskeletal disorders symptom questionnaire to the workers. A closing conference was held on the afternoon of April 30, 1998.

BACKGROUND

Inland Eastex, a division of the Temple–Inland Company, employs about 1200 workers in the manufacture of bleached paper. The plant is about 50 years old. The Company's final product at this site is rolled paper stock, which is delivered to customers in a variety of sizes.

As part of the production, paper is wound onto a thick cardboard tube called a core. Cores are cut and delivered to the paper winding machines by core area workers. The ends of each core are reinforced with a wooden or a compressed wood chip disk called a plug. Workers place these plugs at each end of a core by hand and drive them into place with a hammer.

Since the 1995 restructuring and downsizing of the Company, which placed the Eastex plant organizationally under the Inland portion of Temple–Inland, core saw operators have plugged cores. Previously, cores were plugged by a designated worker at each of the four winding machines after they were delivered to the machines by the core saw operators. Gradually, the plugging task was transferred from the winding area to the finishing department, where cores are now plugged exclusively. However, winding machine operators can plug cores if there is a scheduling irregularity or an emergency need for plugged cores. To compensate for the loss of the four winding machine workers to plug cores and to relieve the core saw workers of the trauma incurred by hammering the plugs, the company developed a mechanical device ("the *green machine*") for plugging cores up to 36 inches in length. Safety personnel were concerned about the musculoskeletal effects of hammering the plugs into the cores. To use the machine, the core is placed horizontally between two circular disks powered by pneumatic plungers. The surface height of the machine is 34 inches. Cradles attached to the disks with screws can be adjusted to allow for cores of various diameters to be plugged properly by the machine. (The plungers must strike the core plugs directly in the center to avoid the need for multiple plunger actuations.) The distance between the disks can be adjusted with a hand crank, and the plungers are activated by pulling a lever with each hand. The machine is mounted on wheels so it can be moved around in the work place. At the time of the NIOSH visit, the machine had been used infrequently because it could only insert plugs for about one–half of the types of cores produced, there were some technical problems with the machine, and using the machine slowed the pace of the work.

For the past 18 years, most workers at the Eastex plant have been on a rotating 12–hour shift that results in an average of 14 days on and 14 days off per month. In the core area of the finishing department, there are four groups of two workers who staff the department during the two 12–hour daily shifts. The shift schedule is such that on a given day, two of the work teams are on duty and two are off work.

Job Descriptions

Core Saw and Plugger

The job is performed by two workers, designated A and B. The A worker (or cutter) is responsible for setting up the core saw and cutting the types of cores needed for the winding machines. This information is received from the winding department by a computer located in the work area. In all, there are 11 core sizes, ranging from 12 to 100 inches in length and 3 to 12 inches in diameter. Company procurement records for the previous year indicate that enough plugs were bought to complete 950 cores per shift. In practice, about 600–800 cores are handled per shift. Records also indicate that approximately 60% of the cores are 12 inches in diameter, and that the average length of a cut core is 45 inches.

The main responsibilities of the B worker (or plugger) are to move raw core stock from storage to the core saw with an overhead crane, load cores onto the saw, bring plugs from the storage area to the work area, plug the cores, load the finished cores onto "buggies" (carts), and deliver the buggies to the winding machines. The plugs are packed in boxes that are either moved to the core saw area by a fork truck or carried by hand. For some customers, the B operator cuts one or two square notches at each end of the core so that the rolls purchased from Eastex can run properly on their paper machines. Cores that must be notched are transported either by hand or with a buggy to the notching machine, notched, and then returned to the main work area to be plugged. The heaviest plugs are those 12 inches in diameter, weighing either four or five pounds, depending on the brand that is used. The heaviest core/plug combination is 47 pounds (100 inch length, 8 inch diameter). The majority of plugged cores weigh less than this amount.

The core saw is located at the top of a long table tilted toward the B operator. After cutting, the cores roll to the front of the table, where they are stopped by a six–inch sill at the end of the table. The top of the sill is 34 inches above the floor. Depending on the length and diameter of the core being cut, the B operator inserts the plugs while the cores are on the table or lifts them off the table and onto the buggy for plugging. Typically, the short– and small–diameter cores are plugged on the table and then lifted to the buggy, while the long– and large–diameter cores are lifted to the buggy, then plugged. In all but a few cases, the plugs are set into the core by hand, and driven into the core with a two–pound ball peen hammer or a lighter rubber mallet. Short, small diameter cores are sometimes plugged by pounding the core on the cutting table.

The bed of the buggy onto which the cores are loaded is120 inches long, 36 inches deep, and 23 inches above floor height. Side panels on either end of the buggy allow cores to be stacked up to 80 inches high. Before a recent modification to the buggies, the sides were high enough to allow stacks of 98 inches in height. The buggies have single 10–inch–diameter wheels at either end and two sets of double wheels 12 inches in diameter at the middle of the bed. This feature prevents the buggy from being level when stationery, but allows the buggies to pivot on the larger wheels for easy rotation when both sides of the cores are plugged on the buggy. The larger wheels at the middle of the buggy also cause rocking of the buggy when someone initially pushes on the handle. The bar type handles are at a height of 53–59 inches (depending on which end of the wheels are on the floor).

When the B operator falls behind in the plugging of cores, help can be requested from either the A operator or an additional worker dispatched from another part of the finishing department. Usually, the B operator can get assistance during peak work loads, but the help from another worker is not always available.

METHODS

Ergonomic

The ergonomic evaluation consisted of observing work activities in the core saw/plugging area of the finishing department for purposes of viewing the various types and sizes of cores that are plugged. The NIOSH team also talked to the supervisors and workers on duty during the evaluation to become familiar with the many aspects of the two jobs. These jobs were also videotaped to document the visible aspects of the jobs, such as postural demands and repetitiveness. This information was extracted from the video through playback analysis either in real time or in slow motion. Work station and work area measurements were also made with a tape measure, and the force to push a buggy loaded with cores was measured with a push/pull force meter. The times spent to perform the various work tasks and the time to plug cores with and without the prototype pneumatic *green machine* were measured with a stop watch.

Medical

The medical portion of this HHE included a review of OSHA 200 logs for the years 1994–1997, and confidential interviews with the workers, which included a musculoskeletal disorders symptom questionnaire. Workers were also asked to report and describe the presence of any pain or discomfort experienced during the previous 12 months, and to relate the occurrences with the physical aspects of their job.

EVALUATION CRITERIA

Musculoskeletal injuries or disorders, such as low back pain, tendinitis, and carpal tunnel syndrome, are often associated with job tasks that include: (1) repetitive, stereotyped movement about the joints; (2) forceful manual exertions; (3) lifting; (4) awkward work postures; (5) direct pressure on nerves and soft tissues; (6) work in cold environments; or (7) exposure to whole–body or segmental vibration (Armstrong, Radwin, and Hansen, 1986; Gerr, Letz and Landrigan, 1991; Rempel, Harrison and Barnhart, 1992). The risk of injury appears to be increased as the intensity and duration of exposures to these factors increases and the duration of recovery time is reduced (Moore and Garg, 1995). Although personal factors (e.g., age, gender, weight, fitness) may affect an individual's susceptibility to musculoskeletal injuries/disorders, studies conducted in high–risk industries show that the risk associated with personal factors is small when compared to that associated with occupational exposures (Armstrong et al., 1993).

In all cases, the preferred method for controlling and/or preventing work–related musculoskeletal disorders (MSDs) is to design jobs, work stations, tools, and other equipment items to match the physiological, anatomical, and psychological characteristics and capabilities of the worker. Under these conditions, exposures to task factors considered potentially hazardous can be reduced or eliminated.

The specific criteria used to evaluate the task demands of the core saw and plugging jobs at Eastex were workplace and job design criteria found in the ergonomics literature and recommendations for acceptable lifting weights found in the NIOSH Revised Lifting Equation (Waters et al., 1994).

The NIOSH Lifting Equation (NLE) is a tool for assessing the physical demands of two–handed lifting tasks. A full description of the components of the NLE is provided in Appendix A. In brief, the equation provides a Recommended Weight Limit (RWL) and a Lifting Index (LI) for a lifting task, given certain lifting conditions. The RWL is the maximum weight that can be handled safely by almost all healthy workers in similar circumstances. The LI is the ratio of the actual load lifted to the RWL. Lifting tasks with an LI $\leq$1.0 pose little risk of low back injury for the majority of workers. Tasks with an LI > 1.0 may place an increasing number of individuals at risk of low back pain or injury. Many researchers believe that tasks with an LI > 3.0 pose a risk of back injury for most workers (Waters et al., 1994).

RESULTS

Ergonomic

The main ergonomic risk factors for the core saw and core plugging jobs are lifting the cores from the cutting table to the buggy, lifting and carrying boxes of plugs from the storage area, trunk flexion while reaching for cores on the cutting table, hammering the plugs into the cores, and pushing the loaded buggies out of the work area. Cores that require notching, and cores that are plugged using the *green machine,* can add up to two lifts per core.

Quantitative Risk Factor Assessments

Lifting Cores

Lifting the cores from the cutting table to the buggy can be done with the load held close to the body, with little or no twisting, and with good hand–to–load coupling. These factors are important to reduce the risk of back pain and injury. They also are factors that are considered when using the NIOSH Lifting Equation (NLE), which is described in Appendix A. The lifts are initiated at the cutting table (28–inch height) and are loaded onto the buggy to heights ranging from 23 to 80 inches. Given this height range, the acceptable core weight for lifting from 600 to 800 cores per shift is between 26 and 30 pounds. When the *green machine* is used or cores are notched, adding up to two lifts per core, the acceptable range becomes 18 –24 pounds, assuming the same range of end point lifts and number of cores per shift. (Notching can add three lifts to a core if it is loaded onto a buggy, pushed to the notcher, and loaded onto the green machine and then back to the buggy. Relatively few cores are notched in this manner, so this special case was not taken into consideration for this analysis.) Note: Even though cores can be stacked up to 80 inches on the buggy, the maximum end of lift height used in the NLE calculations was 70 inches, because the NLE is not defined for lifts made above 70 inches.

Lifting Plugs

The smaller–diameter plugs (3, 4, and 5 inches) are packaged in boxes weighing between 50 and 60 pounds, and these boxes are sometimes lifted and carried by hand. The larger–diameter plugs are packed in bulk and must be moved to the work area with a hand truck or fork lift. After the box is opened, the workers carry stacks of individual plugs to where they will be used in the plugging area.

For occasional lifting of full boxes of small cores from the floor to the cutting table, the NLE indicates that the load should not weigh more than about 27 pounds. Full boxes of 3–, 4–, and 5–inch cores weigh up to twice this amount, indicating an increasingly hazardous lifting condition for most workers (Lifting Index, LI > 2).

For the larger plugs, lifted individually, the NLE recommends total stack weights of no more than about 30 pounds, which means no more than six 12–inch plugs, ten 10–inch plugs or fifteen 8–inch plugs should be lifted at one time.

Sample Calculation of Average Lifting Conditions

The following example is an estimate of the effects of the total amount of lifting that takes place in an average day of work at the core saw/plugger. These assumptions were made: the number of cores per day is 700 (the average of 600 and 800); the number of lifts per core is 2 (average of 1 and 3); the initial height of the lift is 28 inches (cutting table height), and the destination height is 51.5 inches (average of 23 and 80 inches). The average weight used is 20 pounds, based on an 8–inch diameter core (240–inch core weighing 83 pounds), 45 inches in length (average core length estimated by the company), and 4.5 pounds total for two plugs; boxes of plugs weighing 55 pounds (average of 50 and 60 pounds) are lifted occasionally from the floor to the cutting table once per 5 minutes or less; and finally, during the same lifting period, stacks of individual plugs are carried from the cutting table to the average height of the buggy (51.5 inches). The calculation is based on 1400 plugs, 10 plugs/stack = 140 stacks (12/hour, 0.20/minute), average weight = 30 pounds/stack.

The Cumulative Lifting Index (CLI) for the three lifting tasks taking place during a 12– hour period is 2.3. This number is between the areas of increased lifting hazard and unacceptable lifting conditions described in the Evaluation Criteria. The main reason for the elevated CLI is lifting the full boxes of plugs weighing 55 pounds. Removing this task from the calculation so that it includes only the tasks of plugging and stacking the cores, and hand–carrying stacks of cores instead of full boxes, reduces the CLI to 1.0.

Pushing Carts

Three samples of the force needed to set the buggy in motion averaged 26.6 kilograms (20.7 kg., 25.6 kg., and 33.5 kg.). Each sample was taken for a buggy loaded with cores of a different size. This amount of force (26.6 kg.) is acceptable for about 75% of males and 25% of females, assuming one push every 30 minutes, for a distance of about 50 feet (Snook and Ciriello, 1991). The maximum force measured to set a full buggy in motion (33.5 kg.) is acceptable for 50 % of men and 10% women, but only when the frequency of pushing is once or less per eight hours. The Snook data indicate that maximum push forces occur at handle heights of 37 inches for males and 35 inches for females, which is somewhat lower than the 53 to 59 inches at which the buggy push bars are placed.

Hand Plugging Versus Machine

The average time to plug and load 101 cores of various sizes by hand was computed to be about 0.2 minutes per core. This time was calculated from several videotape samples lasting a total of 20 minutes. Video samples totaling 16 minutes were analyzed for 41 cores plugged with the *green machine* and stacked on the buggy, an average time of about 0.4 minutes per core. For 34 cores of the same size and type that were analyzed using both methods, the average time was 0.36 min/core by machine and 0.16 min/core by hand, or approximately 2.25 times longer using the machine than by hand.

One of the issues surrounding the use of the *green machine* was whether there was sufficient time for the core area workers to use it, given the number of daily activities that are performed in the area. Company representatives reported that time studies of the core plugging job estimated that approximately 30 –35% of a B operator's time is devoted to plugging cores by hand. For a 12 hour shift, this time would be 3.6 to 4.2 hours. Assuming that the *green machine* approximately doubles the time to plug cores, the daily time plugging cores while using it could take up to 8.4 hours per 12–hour shift. It should be noted, though, that using the results of the time studies indicates that plugging between 600 and 800 cores per day would take 2 to 2.7 hours by hand and 4 to 5.4 hours by machine, somewhat less time than what the company representatives estimated.

Other Risk Factors

No quantitative measurements were made regarding the hammering of plugs or the bending at the waist to plug cores at the cutting table. However, it must be considered that these activities occur while the other job tasks take place and are recognized factors in the development of musculoskeletal disorders of the upper extremity and back. Carpenters and other trades workers who use hammers suffer from work–related musculoskeletal disorders of the upper extremity due to frequent grasping, repetitive wrist motion, and impulsive vibration to the limbs from hammering (Atterbury et al., 1994). Trunk flexion (forward bending) as little as 20° is associated with local muscle fatigue and low back pain (Van Wely, 1970).

Miscellaneous Observations

The area in which the core saw/plugging operations are located is very large, requiring a considerable amount of walking to obtain and arrange materials. Plugs stacked at the far end of the space were usually brought to the work area by lift truck, but when only a few plugs were needed to complete a set of cores, and a truck was not in the area, the workers would walk to the far end of the core saw area to get plugs.

There were no designated areas in the work space for boxes of plugs to be stored. Often, the workers had to place full boxes of plugs wherever they could find floor space in the work area and then walk back and forth between the plugs and the cutting table or buggy while plugging cores. Material handling equipment was observed to be in the way of the core plugger during a plugging or notching operation. The non–optimal layout of materials and fixtures in the work space accounted for some of the time workers needed to perform their daily, routine tasks.

Medical

OSHA 200 Logs Review

Review of the OSHA 200 logs (Table 3) indicated that the incidence rates of reported injuries fluctuated in the plant as a whole during the years 1994–97, while steadily increasing in the finishing department. The Company introduced a "safety incentive" program in 1995, which may have influenced the plant–wide decreases seen in 1995 and 1996 compared to 1994. Similarly, the increase in 1997 from 1996 for total plant injuries and illnesses may have corresponded to the end of the safety incentive program in 1997.

Incidence rates of injuries and illnesses increased each year from 1994 (8.7 per 100 workers) to 1997 (22.8 per 100 workers) in the finishing department. During this period of time, the task of core plugging was gradually being transferred from the winding to the finishing department. The biggest increase in reported injuries and illnesses in the finishing department was from 1996 (14.0 per 100 workers) to 1997 (22.8 per 100 workers), the time period when the safety incentive program was dissolved and the transfer of core plugging to the finishing department was completed.

In 1997, eight injuries occurred in the finishing department, three of which were attributed to core area workers. All three were musculoskeletal problems: one shoulder strain, one elbow tendinitis, and one with both shoulder and elbow strains.

Table 3
Incidence Rates of Injuries and Illnesses Reported for the Years 1994–1997

OSHA 200 Log Summary – Inland Eastex Co. (Rates per 100 Workers)

Year	Administrative Changes	Total Plant	Finishing Department
1994		13.7	8.7
1995	Safety incentive program begins	10.9	13.3
1996	Core plugging incorporated into finishing in Nov. 1996	6.1	14.0
1997	Safety incentive program ends	9.2	22.8

Medical Interviews and Questionnaires

During the evaluation, two of the four work groups were working, representing four of eight core area employees. One of the remaining four workers was also available for interviews, bringing the total to five workers interviewed.

Four of the workers complained of shoulder pain and one reported forearm pain. Three of the five workers indicated that they had seen a health care provider regarding their symptoms. All five workers attributed their pain to the task of core plugging. Other areas of discomfort described by the workers involved the elbow region and the lower back.

All interviewed workers offered comments and complaints about the prototype core plugging machine. The most common comments were:

1. Core plugging was much slower using the machine, making it difficult for workers to finish all of their work on time.

2. The machine led to low back discomfort because of the need to bend over it.

3. The workers had to repeat the compression several times because of alignment problems, and they often had to use the hammer to complete the core/plug assemblies.

4. The workers were not adequately involved in designing the machine.

In addition, all workers felt that the number of tasks required of the B operator was more than could be done in the shift. Most were able to do their job only if they had help.

DISCUSSION

Medical

Irrespective of the influence of the introduction and elimination of the safety incentive program over the period 1995–97, the reporting of injuries and illnesses coincides well with the gradual increase in work load required of the core saw/plugger operators as the plugging of cores was shifted to the finishing department. Safety and health officials at the plant were prudent in addressing the increase in reported injuries by developing the *green machine*, which was intended to relieve the workers of the most difficult part of their job, namely hammering the plugs into the cores.

Nearly all of the ergonomic risk factors associated with the sawing and plugging tasks were attributable to the B worker's job responsibilities, yet the A workers interviewed indicated the same type of aches and pains from bending over, lifting, and hammering as the B workers reported. This suggests that the A workers were experiencing musculoskeletal injury symptoms from helping the B workers complete their job tasks.

Ergonomic

The NLE was designed to analyze lifting tasks which take place during an 8–hour work day. Using the equation to calculate a lifting index (LI) for lifting periods that are spread over a 12–hour work shift stretches the constraints of the equation somewhat, but this is more valid than the over–estimation of risk that would occur if the lifting frequency were calculated as if all lifting occurred during an 8–hour shift. In reality, though, most of the lifting of plugs and cores takes place in a short interval during the work shift. However, because the number of lifts was averaged over the 12–hour work period, the recommended weights presented in the Results Section are somewhat conservative and may not be as protective of the workers as the cumulative lifting index (CLI) for the tasks suggests. As such, the sample calculations presented in the Results Section represent a best case scenario for the hazard due to the core area lifting activities; the actual hazard may be greater than the NLE can evaluate.

Many of the calculations presented in the Results Section were based on assumptions made concerning the work load presented by a job that can vary considerably from day to day, both in work mix (number and sizes of cores) and staffing support. The time study estimates of the amount of the day a B operator spends plugging cores were less than the estimate provided by the Company personnel, indicating that perhaps some activities associated with the normal plugging of cores may not have been taken into account by our time study analyses. However, a projection that plugging cores could take over 8 hours in a 12–hour shift, if done exclusively with the *green machine*, indicates that there would be little time for normal breaks and lunch periods, let alone the other tasks performed (loading the saw, getting plugs, notching, delivering the cores to the winders, etc.), irrespective of the day–to–day variability of work load and staffing. No matter what time and work load assumptions are made, the day of a B worker is very busy and not in need of anything that could take more time. Moreover, the work load can be viewed as being moderate or severe, depending on what tasks are performed and how many of them are performed by the B worker. A CLI of 2.3 is considered to be in the range of work load where most workers would be at an elevated risk of injury to the low back from lifting. The analyses also show that the risk of injury can be substantially lowered if the unassisted lifting of boxes of plugs is eliminated (CLI = 1.0).

Even though the NLE examples indicate a safe lifting level for most workers if lifting of 55 – 60 pound boxes is eliminated, and if the lifting is spread evenly over the work shift, studies of fatigue and extended work periods indicate that as workers progress into a work day, the level of work producing an acceptable amount of fatigue decreases (Rosa, et al., 1998). This outcome is likely to occur more dramatically in work shifts greater than eight hours. This finding from the Rosa study suggests that workers in the core saw area would have to lift at higher levels during portions of the day to compensate for the work capacity decrease that likely occurs toward the end of the shift. This would require lifting at rates that increase the CLI to above 1.0, potentially producing a hazardous lifting situation. Bursts of activity also routinely occur when the winding department sends a rush order for cores, which would also require the workers to lift at rates exceeding what was assumed in the NLE calculations. It should be noted that the above discussion does not include the risk of injury to the workers associated with pushing the carts, hammering plugs, and performing the other repetitive tasks which the video analysis indicated to be considerable. Similarly, the discussion does not include help to the core plugger by the A operator or an additional worker.

Analysis of the push forces required to move the buggies out of the core saw area indicated that the loads are excessive for most workers, unless performed rarely. A lower handle (36– 44 inches) would reduce the risk to workers, as would lower stack heights (Eastman Kodak,1986). From a lifting standpoint, stack heights should be no more than 70 inches; design criteria indicate that the height should be 55 inches or lower for improved visibility when maneuvering the buggies. If the stack height is not reduced, the buggies should be equipped with t–bar handles so they can only be pulled. In either case, there should be wheels at the four corners because a loaded cart weighs more than 500 pounds (Eastman Kodak, 1986). Lowering the stack height would increase the number of buggies loaded per day and delivered to the winding machines, but it would reduce the risk of injury to the workers. Most of the buggies are pushed manually out of the work area only, a distance of 40 or 50 feet, and then delivered to the winding machines with a motorized cart.

Green Machine

A mechanical device like the *green machine* is a good concept since it relieves the worker of 1200 –1600 hammer strikes per day, eliminates hammering at above–shoulder heights, and can be placed where it is needed. However, it is slower than manual plugging, it increases the frequency and weight of lifting, it is useful only for about one–half of the cores produced, and it requires too much time for set up (cradle height) and adjustment (core length). Time studies indicated that the machine slows the worker by about one–half, mainly due to multiple actuations of the plunging cylinders necessitated by design–related off–center hits. Considering these design deficiencies, a better machine should be developed to insert plugs, having the following features:

1. Ease of set up and adjustability

2. Efficiency – plugs inserted with one actuation

3. Convenient transfer between the cutting table and the delivery buggy

4. The same amount or less time per core than plugging by hand

5. Ability to plug all core sizes

CONCLUSIONS

1. The occurrence of injuries and illnesses in the finishing department has increased since core plugging was transferred from the winding department.

2. "A" workers experience musculoskeletal aches and pains from helping the "B" workers.

3. A better mechanized alternative to hammering the plugs into place would reduce the risk of injury to the workers and should be sought. Worker input and evaluation of the design may enhance the utility and worker acceptance of future prototype mechanical devices for inserting plugs.

4. The B worker's job is comprised of a number of intensive material handling and repetitive motion activities that occupy a considerable portion of the day and are fatiguing to the workers. In order to reduce the risk of injury and fatigue, the B worker needs either assistance from other workers or a mechanical alternative to hand plugging of cores that does not require more of the worker's time and/or effort.

5. In general, the physical work load in the core saw area is within the capability of most workers, but only if some tasks such as hammering plugs, lifting full boxes of plugs, and pushing fully loaded buggies are not routinely performed.

6. The layout of the core saw area and the placement of materials and equipment in the area add to the physical load and time constraints of the workers.

RECOMMENDATIONS

1. Continue efforts to provide a more effective mechanized method to plug cores. The device should be easy to use and adjust and not take more time or effort than hand plugging. The existing *green machine* is an adequate prototype and would be more appropriate if performance deficiencies were corrected. A design that plugs multiple cores at a time and delivers cores more directly to the transport buggy is more desirable. A roll conveyor or a delivery chute linking the plugging device to the buggy is an example of a modification that would reduce lifting and walking between the plugger and the buggy.

2. Add a worker to the core saw department during the busiest times of the day so that the B worker can work at the steady rate assumed in the lifting calculations presented in the Results Section.

3. Redesign the transport buggies to reduce the amount of force needed to set them in motion and roll them out of the work area. The height of the buggy sides should be reduced so that stack heights do not exceed 70 inches. Design criteria for carts and buggies recommend heights of no more than 55 inches for purposes of visibility, but visibility is not necessarily a critical feature for buggies that are usually delivered to the winding machines with a motorized vehicle. The buggies should also have wheels on all four corners, and handle heights should be in the range of 36–44 inches. A push handle height and full load weight combination that can be rolled with 10 kg. of force would be suitable for over 90% of males and 75% of females.

4. Eliminate the unassisted lifting of full boxes of small plugs. Calculations presented in the Results Section indicate that even the occasional lifting of boxes of plugs weighing 55–60 pounds increases the Cumulative Lifting Index (CLI) to more than 2, which poses an increased risk for lifting–related low back pain for workers. Similarly, the combined weight of loose plugs carried to the work area by hand should not exceed 30 pounds.

5. Eliminate the unassisted lifting of core/plug combinations that exceed 30 pounds. Most of the cores weigh less than this amount, but as noted earlier, some can weigh up to 47 pounds. When cores heavier than 30 pounds are being handled, a material handling device, or help from an additional worker should be sought.

6. Improve the flow of work in the area by relocating materials and equipment used to plug cores. Key aspects of the reorganization of the area would be to designate locations for plugs, buggies, the notcher, and waste bins so that they are close to the cutting table and can be accessed easily without interference from material handling equipment, empty transport carts, and other equipment in the area. A reorganization of the area would also facilitate the integration of mechanical plugging devices into the work area.

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Table 1
Frequency Multiplier (FM) for NIOSH Lifting Equation

Frequency Lifts/min	Work Duration					
	≤ 1 Hour		≤ 2 Hours		≤ 8 Hours	
	V < 75	V ≥ 75	V < 75	V ≥ 75	V < 75	V ≥ 75
0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

† Values of V are in cm; 75 cm = 30 in.

Table 2
Coupling Multiplier (CM) for NIOSH Lifting Equation

Couplings	V< 75 cm (30 in)	V $\geq$ 75 cm (30 in)
	Coupling Multipliers	
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

APPENDIX A

The Factors Comprising the NIOSH Revised Lifting Equation

Calculation for Recommended Weight Limit

RWL = LC * HM * VM * DM * AM * FM * CM
(* indicates multiplication.)

Recommended Weight Limit

Component			Metric	U.S. Customary
LC	=	Load Constant	23 kg	51 lbs
HM	=	Horizontal Multiplier	(25/H)	(10/H)
VM	=	Vertical Multiplier	(1–(.003|V–75|))	(1–(.0075|V–30|))
DM	=	Distance Multiplier	(.82+(4.5/D))	(.82+(1.8/D))
AM	=	Asymmetric Multiplier	(1–(.0032A))	(1–(.0032A))
FM	=	Frequency Multiplier	(From Table 1)	
CM	=	Coupling Multiplier	(From Table 2)	

Where:

H = Horizontal location of hands from midpoint between the ankles.
Measure at the origin and the destination of the lift (cm or in).

V = Vertical location of the hands from the floor.
Measure at the origin and destination of the lift (cm or in).

D = Vertical travel distance between the origin and the destination of the lift (cm or in).

A = Angle of asymmetry – angular displacement of the load from the sagittal plane.
Measure at the origin and destination of the lift (degrees).

F = Average frequency rate of lifting measured in lifts/min.
Duration is defined to be: < 1 hour; < 2 hours; or < 8 hours assuming appropriate recovery allowances.

For Information on Other
Occupational Safety and Health Concerns

Call NIOSH at:
1–800–35–NIOSH (356–4676)
or visit the NIOSH Homepage at:
http://www.cdc.gov/niosh/homepage.html

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